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(54) Backflow of exhaust gas through exhaust valve into cylinder of i.c. engine

(57) An exhaust valve 12 in a cylinder head 4 is allowed to partially open during part of the working cycle of an engine, when the pressure in the combustion chamber 2 is lower than that in the exhaust channel causing exhaust gas to flow back into the cylinder. A shield or screen portion 24 extending partially around the exhaust valve seat 22 causes the exhaust backflow to swirl along the inside wall of the cylinder. Charge from an inlet valve may then be caused to swirl in the central zone of the cylinder. Such an arrangement is designed to give low NOx and HC emissions and allow for a lean mixture to be burnt as the presence to the exhaust gas next to the cylinder wall prevents fuel droplets forming on the wall.

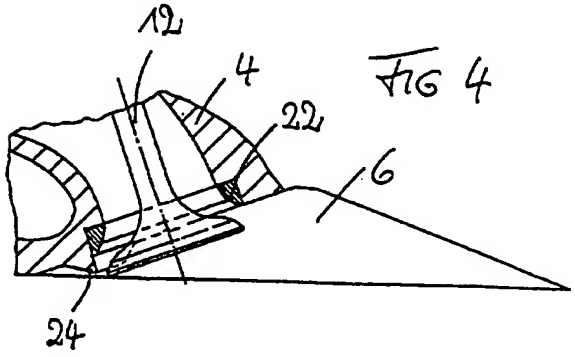

FIG 4

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FIG 1

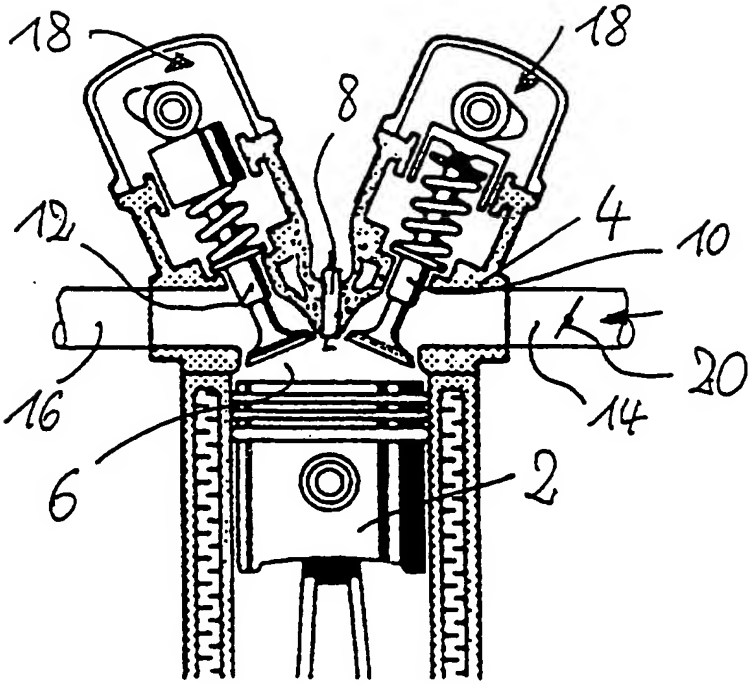

18
18
8
12
4
10
20
16
14
6
2

FIG 2

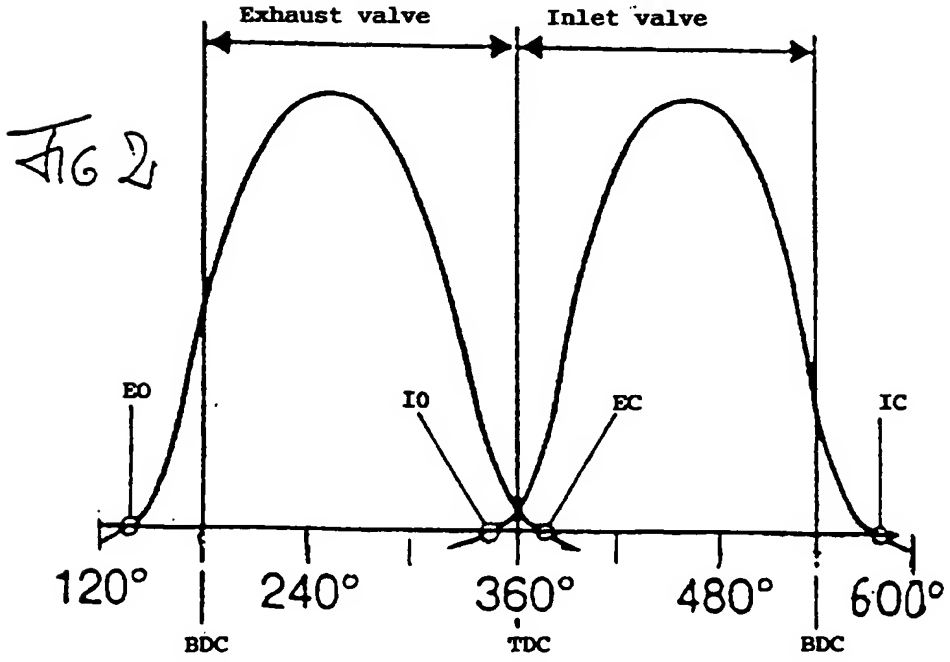

Exhaust valve
Inlet valve
EO
IO
EC
IC
120°
240°
360°
480°
600°
BDC
TDC
BDC

FIG 3

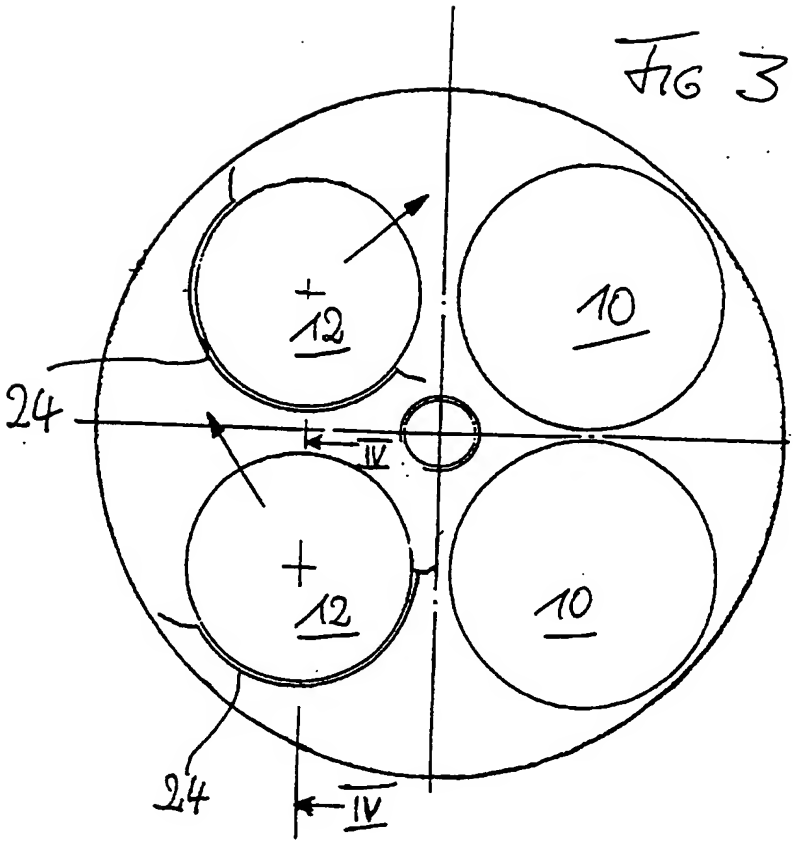
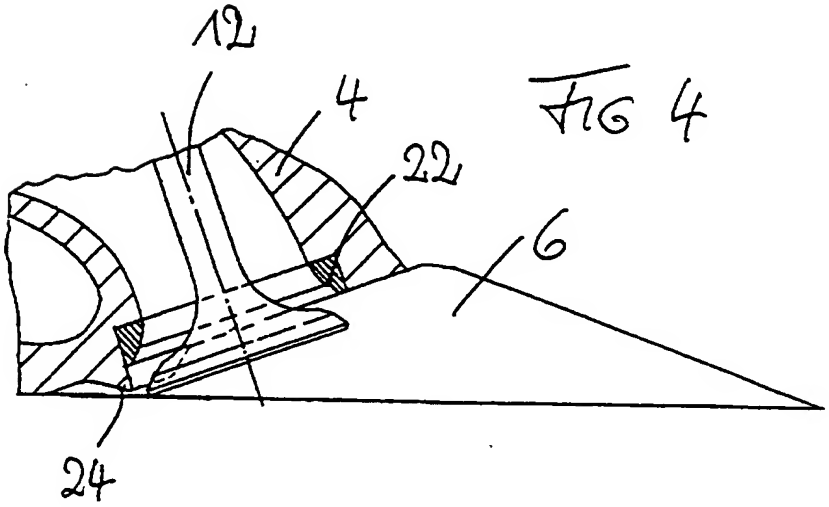


FIG 4



Method of improving the combustion chacteristics in an internal combustion engine and an internal combustion engine

The invention concerns a method of improving the combustion characteristics in an internal combustion engine, and an internal combustion engine.

Increasingly strict exhaust gas regulations and the need to reduce the level of fuel consumption are setting high requirements in terms of the management and control systems for the operating characteristics of internal combustion engines or influencing the combustion characteristics in such engines.

A common method of improving the operating characteristics of or the combustion characteristics in internal combustion piston engines in the part-load range involves causing the fresh charge, in the part-load range, to flow into the combustion chamber in a directed manner in such a way that a swirl flow (rotational flow about the axis of the piston movement) and/or a tumble flow (rotational flow about an axis which is perpendicular to the direction of the piston movement) is formed in the combustion chamber. That is achieved by the incorporation of screening means in the inlet duct, by rendering inoperative an inlet valve when there are a plurality of inlet valves in each cylinder, and so forth. Such measures are intended to achieve an increased charge movement which improves the mixture formation and thus permits better combustion.

In accordance with the present invention, there is provided a method of improving the combustion characteristics in an internal combustion engine comprising a cylinder having a piston therein defining a combustion chamber, an induction means, an exhaust means, an inlet valve for temporarily communicating the combustion chamber with the induction means, and an exhaust valve for temporarily communicating the combustion chamber with the exhaust means, wherein the exhaust valve is partially opened at least during a part of the working cycle during which the pressure in the region of the combustion chamber that adjoins the exhaust valve is lower than the pressure in the region of the exhaust gas means that adjoins the exhaust valve, and the

flow passage formed by the partial opening of the exhaust valve along the exhaust valve seat is of such a configuration that an exhaust gas backflow which occurs through same flows in a directed fashion into the combustion chamber.

As will be seen from a description of a preferred embodiment hereinafter the method of the present invention can improve the operating characteristics of an internal combustion piston engine, more especially in the part-load range thereof, enhancing the combustion characteristics in the combustion chamber of the internal combustion engine such as to afford improved fuel consumption and reduced emission levels, using a simple structural configuration. It will be shown that the method according to the invention can provide that the exhaust gas backflow which occurs during a part of the working cycle is utilised alone or additionally to form a directed flow in the combustion chamber, which improves the thermodynamic combustion conditions for fresh charge which flows into the combustion chamber when the inlet valve is opened. In that case, the kinetic energy of the fresh charge can be increased, more intensive mixing of the fresh charge with exhaust gas can be achieved, a film of fuel which is deposited on the combustion chamber wall can be broken up, and so forth.

A preferred feature of the method according to the invention provides that the exhaust gas backflow forms in the combustion chamber a flow which is near to the wall and which rotates about an axis. In that way it is possible to create an exhaust gas envelope which is near the wall and which has a desirable influence on combustion.

A further preferred feature of the method according to the invention provides that the exhaust gas backflow forms in the combustion chamber a swirl flow which extends around the axis of the cylinder. This is particularly advantageous as such a swirl flow forms a stable macroscopic rotational flow which is near the wall and in the core region of which fresh charge can be concentrated, the sparkplug normally being arranged in that core region in the case of Otto-cycle engines.

In a preferred embodiment of the invention fresh charge is introduced into a radially inner region of the swirling exhaust gas backflow and at the time of combustion is separated from the combustion

chamber wall by a layer of exhaust gas. This provides that the fresh charge is "packed" into an exhaust gas envelope, by virtue of the exhaust gas backflow which lies against the combustion chamber wall surface forming an exhaust gas layer which separates the incoming or burning fresh charge from the combustion chamber wall. As a result thereof, the capability of operating with a lean mixture and the residual gas compatibility are improved, the levels of hydrocarbon emissions are reduced and the wall heat losses or cooling heat losses are reduced, which results in advantages in terms of consumption. The exhaust gas layer which is adjacent the wall can already come to rest at the time of combustion of the fresh charge or just prior to that time, in other words, the kinetic energy of the rotational flow can be dissipated.

In accordance with another aspect of the invention there is provided an internal combustion engine comprising a cylinder having a piston therein defining a combustion chamber, an induction means, an exhaust means, an inlet valve for temporarily communicating the combustion chamber with the induction means, an exhaust valve for temporarily communicating the combustion chamber with the exhaust gas means, and a means for controlling opening and closing of the valves such that the exhaust valve is partially opened at least during a part of the engine working cycle during which the pressure in the region of the combustion chamber that adjoins the exhaust valve is lower than the pressure in the region of the exhaust means that adjoins the exhaust valve, wherein the flow passage formed by the partial opening of the exhaust valve along the exhaust valve seat thereof is such that an exhaust gas backflow which occurs through it flows in a directed fashion into the combustion chamber.

In a preferred embodiment of the internal combustion engine the exhaust valve seat is provided over a part of its periphery with a screening means which reduces the through-flow cross-section when there is a short valve lift, wherein the screening means faces generally in a peripheral direction of the combustion chamber, which peripheral direction is directed about the axis of the piston movement.

Another preferred feature provides that the internal combustion

engine has first and second exhaust valves for the or each cylinder, each having a respective exhaust valve seat, the screening means of which face in the same direction in the peripheral direction.

With the above-outlined fundamental structure of an internal combustion engine of the invention, the method of the invention necessarily takes place in that internal combustion engine.

An embodiment of the present invention will now be described by way of example with reference to the accompanying drawing in which:

Figure 1 is a view in cross-section through a butterfly valve-controlled reciprocating-piston internal combustion engine,

Figure 2 shows the valve lift curves of the internal combustion engine shown in Figure 1,

Figure 3 is a view onto a cylinder head from the piston, and

Figure 4 is a detail view in cross-section taken along line IV-IV through the cylinder head in Figure 3.

Referring to Figure 1 an internal combustion engine has at least one piston as indicated at 2 operating in a respective cylinder, defining a combustion chamber 6 which is provided in a cylinder head 4 and into which a sparkplug 8 extends centrally from above. The charge change is controlled by way of one or more inlet valves as at 10 and one or more exhaust valves as at 12 which temporarily or selectively controlledly communicate the combustion chamber 6 with an induction system 14 and an exhaust gas system 16 respectively. The valves 10 and 12 are controlled by a cam drive arrangement 18 co-operating with the crankshaft (not shown) of the internal combustion engine.

Figure 2 shows on the abscissa the angular position of the crankshaft (not shown) while on the ordinate it shows the associated openings of the exhaust valve 12 and the inlet valve 10 respectively. As will be seen from Figure 2, opening of the exhaust valve begins at about 130° crank angle (EO), in which case the exhaust valve 12 is already comparatively wide open in the region of the bottom dead centre (BDC) of the crankshaft and closes after the top dead centre (TDC) of the crankshaft (at EC). The inlet valve 10 opens before the top dead centre of the crankshaft (at IO) and closes after the bottom dead centre of the crankshaft (at IC).

As can be seen the inlet valve 10 already opens while the exhaust valve 12 is still open. In the range of high reduced pressures in the induction system 14, as are achieved when the butterfly valve 20 (Figure 1) is substantially closed, that valve overlap has the result that the reduced pressure downstream of the butterfly valve 20 in the induction system 14 is extended into the combustion chamber 6 and further increased therein when the piston 2 has moved beyond the top dead centre point, whereby there is a backflow of exhaust gas out of the exhaust gas system 16 along the exhaust valve 12, which is still partially open, into the combustion chamber 6.

That backflow is used deliberately by virtue of the exhaust valve seat being for example of the configuration as shown in Figures 3 and 4.

Figure 3 is a view from below of part of a cylinder head with two inlet valves 10 and two exhaust valves 12 per cylinder. Figure 4 is a view in section taken along line IV-IV in Figure 3, with the exhaust valve 12 lifted open, although the section through the inlet valve 10 is not shown for the sake of clarity of the drawing.

As can be seen the cylinder head 4 is provided around a part of the periphery of the exhaust valve seat 22 with a screening or shielding 24 which prolongs the seat into the combustion chamber 6, parallel to the direction of movement of the valve 12. The screening 24 reduces the through-flow cross-section between the exhaust valve 12 and the adjacent wall of the cylinder head 4, over a part of the valve lift. In that respect, as can be seen from Figure 3, the screening 24 is of such a configuration over a respective peripheral region of the exhaust valve seat 22 that an increased through-flow cross-section is available in a peripheral direction of the combustion chamber around an axis defining the direction of movement of the piston, so that, in the event of an exhaust gas backflow, there is an intake flow substantially in the direction of the arrows illustrated in Figure 3. The respective screening 24 can extend for example along about 180° of the periphery of the respective exhaust valve seat 22, with the ends of the screenings 24 being given by a respective radius of the combustion chamber.

The above-described arrangement provides that, in the low-load

range, when the butterfly valve 20 is substantially closed, the exhaust gas backflow forms a swirl flow which extends around the combustion chamber 6 in the peripheral direction thereof around the axis of the piston movement and which surrounds or encloses the incoming flow of fresh charge and concentrates it into the central region of the combustion chamber 6 in which the sparkplug 8 is arranged. That provides for a considerable improvement in the capacity for using a lean mixture, and a considerable improvement in residual gas compatibility, while combustion speed is increased and hydrocarbon emissions and the cooling water losses are reduced. The level of fuel consumption of the internal combustion engine is reduced, with at the same time an improvement in emission characteristics.

In contrast to the charge movement being influenced, in per se known manner, by way of the incoming flow of fresh charge, the exhaust gas backflow as described above only occurs in the low-load range so that there are no disadvantageous effects whatsoever in regard to the full-load range, as occur in the known procedure for influencing the charge movement by way of the incoming flow of fresh charge. The engine as described above thus enjoys an improved combustion performance, while involving relatively minor structural modifications.

It will be appreciated that the above-described embodiment of the invention has been set forth solely by way of example and the invention can be modified in many ways without thereby departing from the spirit and scope of the invention. For example the reduced pressure in the combustion chamber does not have to be produced by way of a butterfly valve, but can be produced directly by influencing the opening functions of the inlet and/or exhaust valve. For certain uses, it may be advantageous for the exhaust valve to be deliberately kept open longer than is shown in Figure 2, by virtue of being able to suitably influence the opening functions of the valves. The screening portions 24 and/or shield means which are mounted on the stem of the exhaust valve could also be of such a configuration that a tumble flow is produced in the combustion chamber, if that is advantageous with a suitable valve configuration, and the position of the sparkplug and the injection nozzle. The invention is not limited to use in Otto-cycle

engines but can also be used in diesel engines. In the case of engines having a plurality of exhaust valves per cylinder, it may be sufficient to provide only one thereof with a screening means. Furthermore, in the case of engines with a plurality of exhaust valves per cylinder, wherein the exhaust valves are of an asymmetrical configuration with respect to a plane passing through their axis and the axis of the cylinder, then, to produce a directed exhaust gas backflow into the combustion chamber, it may also be sufficient to actuate only one of the exhaust valves, as the asymmetry then results in a suitable orientation of the backflow.

CLAIMS:

1. A method of improving the combustion characteristics in an internal combustion engine comprising

a cylinder having a piston therein defining a combustion chamber,

an induction means,

an exhaust means,

an inlet valve for temporarily communicating the combustion chamber with the induction means, and

an exhaust valve for temporarily communicating the combustion chamber with the exhaust means,

wherein the exhaust valve is partially opened at least during a part of the engine working cycle during which the pressure in the region of the combustion chamber that adjoins the exhaust valve is lower than the pressure in the region of the exhaust means that adjoins the exhaust valve, and

the flow passage formed by said partial opening of the exhaust valve along the exhaust valve seat is of such a configuration that an exhaust gas backflow which occurs through same flows in a directed fashion into the combustion chamber.

2. A method as set forth in claim 1

wherein the exhaust gas backflow forms in the combustion chamber a flow which is near to the chamber wall and which rotates about an axis.

3. A method as set forth in claim 1 or claim 2

wherein the exhaust gas backflow forms in the combustion chamber a swirl flow which extends around the axis of the cylinder.

4. A method as set forth in claim 2 or claim 3

wherein fresh charge is introduced into a radially inner region of the swirling exhaust gas backflow and at the time of combustion is separated from the combustion chamber wall by a layer of exhaust gas.

5. A method of improving the combustion characteristics in an internal combustion engine, substantially as hereinbefore described with reference to the accompanying drawing.

6. An internal combustion engine comprising

a cylinder having a piston therein defining a combustion chamber,

an induction means,

an exhaust means,

an inlet valve for temporarily communicating the combustion chamber with the induction means,

an exhaust valve for temporarily communicating the combustion chamber with the exhaust means, and

a means for controlling opening and closing of the valves such that the exhaust valve is partially opened at least during a part of the engine working cycle during which the pressure in the region of the combustion chamber that adjoins the exhaust valve is lower than the pressure in the region of the exhaust means that adjoins the exhaust valve, wherein the flow passage formed by said partial opening of the exhaust valve along the exhaust valve seat thereof is such that an exhaust gas backflow which occurs through it flows in a directed fashion into the combustion chamber.

7. An internal combustion engine as set forth in claim 6

wherein the exhaust valve seat is provided over a part of its periphery with a screening means adapted to reduce the through-flow cross-section of said flow passage when there is a short valve lift, wherein the screening means faces generally in a peripheral direction of the combustion chamber, which peripheral direction is directed about the axis of the piston movement.

8. An internal combustion engine as set forth in claim 7

including first and second exhaust valves each having a respective exhaust valve seat, the screening means of which face in the

same direction in the peripheral direction.

9. An internal combustion engine as set forth in any one of claims 6 to 8

including a plurality of cylinders each with operatively associated piston and at least one inlet valve and at least one exhaust valve, at least one exhaust valve of each cylinder being partially openable by said controlling means during a part of the engine working cycle during which the pressure in the region of the combustion chamber that adjoins the exhaust valve is lower than the pressure in the region of the exhaust means that adjoins the exhaust valve,

and further including a screening means operatively associated with said at least one exhaust valve and adapted to direct an exhaust gas backflow around said at least one exhaust valve into said combustion chamber at least substantially in the peripheral direction thereof.

10. An internal combustion engine substantially as hereinbefore described with reference to the accompanying drawing.

The Patent Office

Application No: GB 9717851.1 **Examiner:** David Glover
Claims searched: 1-9 **Date of search:** 21 January 1998

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.P): F1B

Int Cl (Ed.6): F02D 13/02, 21/04, 21/08; F02F 1/42

Other: Online: WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
A	GB 2114660 A	(Research Corporation)	2-4
X	WO 85/05654	(Schüle) see figure 1 and abstract	1 & 6
X	US 5161497	(Simko *et al*) see column 1 line 64 - column 2 line 9	1 & 6

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.